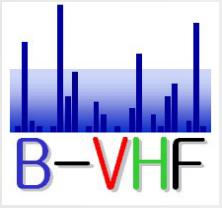


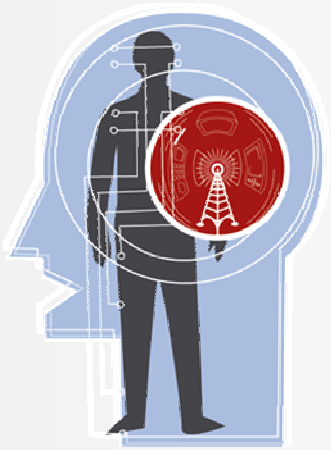
A Multi-Carrier Broadband Communications Concept for ATM in the VHF Band

Presented by J. Prinz (Frequentis GmbH)

27.4.2004 ICNS Fairfax, VA

Overview

- Motivation
- Current VHF Band Situation
- Technical Baseline of Multi Carrier
- Multi-Carrier CDMA
- Transition Aspects
- B-VHF Project



Communication Capacity

Key for growth and major obstacle at once

Air Traffic is lacking the communications capacity that is required to cope with the expected growth!

According to Eurocontrol, Europe runs out of VHF radio channels around 2015!

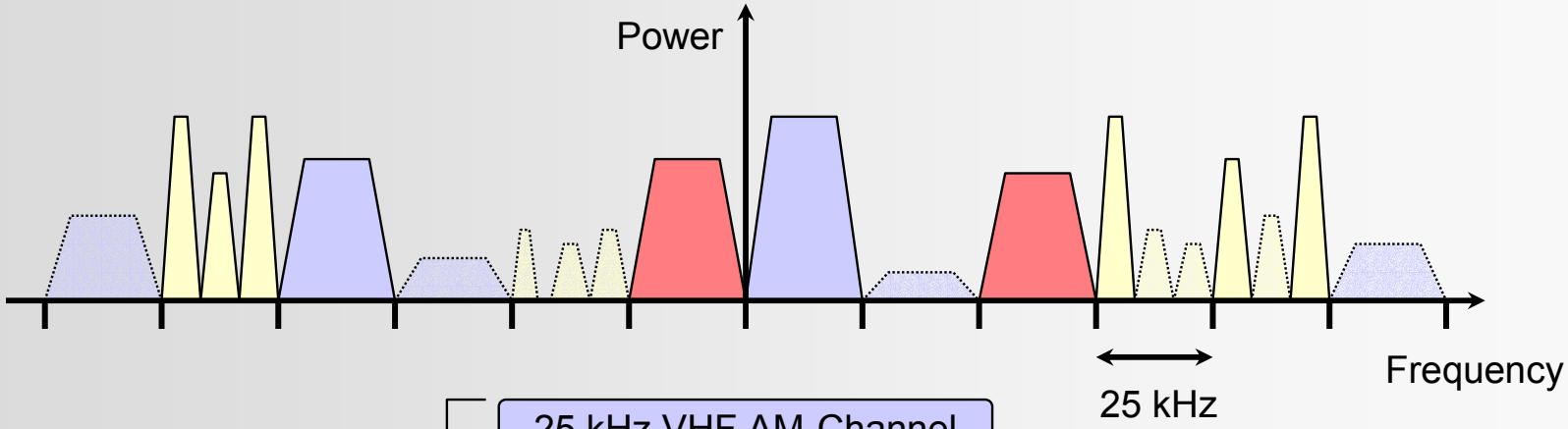
Current VHF Band Situation
General Facts

- VHF COM Band (118-137 MHz) is essential for ATC
  - Narrowband systems with 25/8,33 kHz channel spacing
  - Frequency planning criteria (co-channel interference)
    - Large Frequency re-use distances
- Most channels are used for analog ATS voice communication
  - one VHF frequency per ATC sector
  - DSB-AM modulation / half duplex with 'Listen before PTT' access
  - Voice 'party line' exists between all users on a given channel
  - Some Channels are used for AOC
- Some channels are used for data exchange
  - ACARS airline's data link (~130MHz /25kHz)
  - ATS Datalink at the top of the spectrum (25kHz)

- Existing narrowband systems effectively waste precious spectrum resources!

Current VHF Band Situation

25 / 8.33 kHz channel spacing
Only a part of the allocated channels are used
Not all channels are ‘seen’ with full power all the time



Analog
- 25 kHz VHF AM-Channel
- 8,33 kHz VHF AM-Channel

Digital
- 25 kHz VHF VDL-Channel

Starting Facts for a New System

- Without additional communications capacity European ATM will run into difficulties by ~2015
- VHF remains an attractive candidate for a new system
  - Balance of cost of operations and radio coverage
  - Existing ground infrastructure
- Air Traffic growth demands a broadband communications technology
  - Required bandwidth for future services
  - Profit from commercial developments
  - Enable transitions in a heavily disturbed environment
  - Eurocontrol activities
    - Eurocontrol proposes to initially deploy broadband system in 5 GHz for terminal services and thus free spectrum in VHF
  - European Commission funded activities
- Ideally, a new broadband system should share VHF resources with legacy narrowband systems!

Requirements for a New System

- Easy transition from the current analog system to a new one

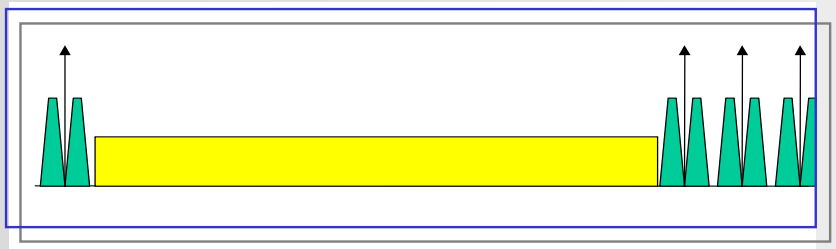
- Increased communications capacity for current and future services
- Efficient radio frequency spectrum utilization

- Cost effective compared to alternative systems
- Improved communications systems security
- Increase robustness against jamming and attacks of ‘phantom controllers’
- Reduce user workload
- Reduce spectrum planning criteria (e.g. re-use distance)

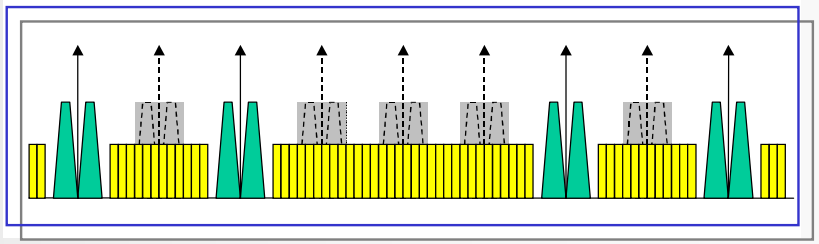
- At all times - SAFETY FIRST

Broadband Approaches

- W-CDMA technology
  - use existing commercial technology in order to reduce cost
  - need continuous spectrum which is not available, thus requiring major rearrangements
  - commercial situation not clear for the envisioned time 2015



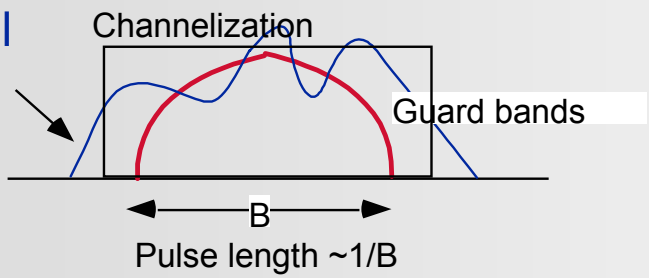
- Multi Carrier technology
  - use commercial technology which will be available at the time of deployment
  - does not require continuous spectrum
  - Higher spectrum efficiency
  - Increased flexibility



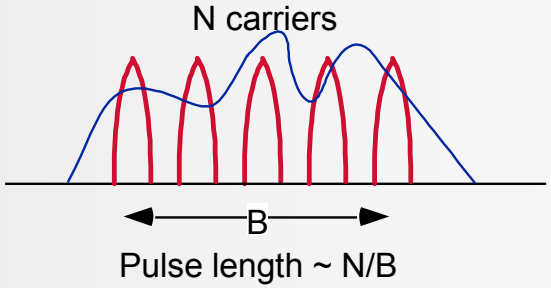
Overlay

Multi Carrier Technology
Motivation

Channel



– Data are transmitted over only one carrier



– Data are shared among several carriers and simultaneously transmitted

Drawbacks

– Selective Fading
– Very short pulses
– ISI is compartively long
– EQs are then very long
– Poor spectral efficiency because of band guards

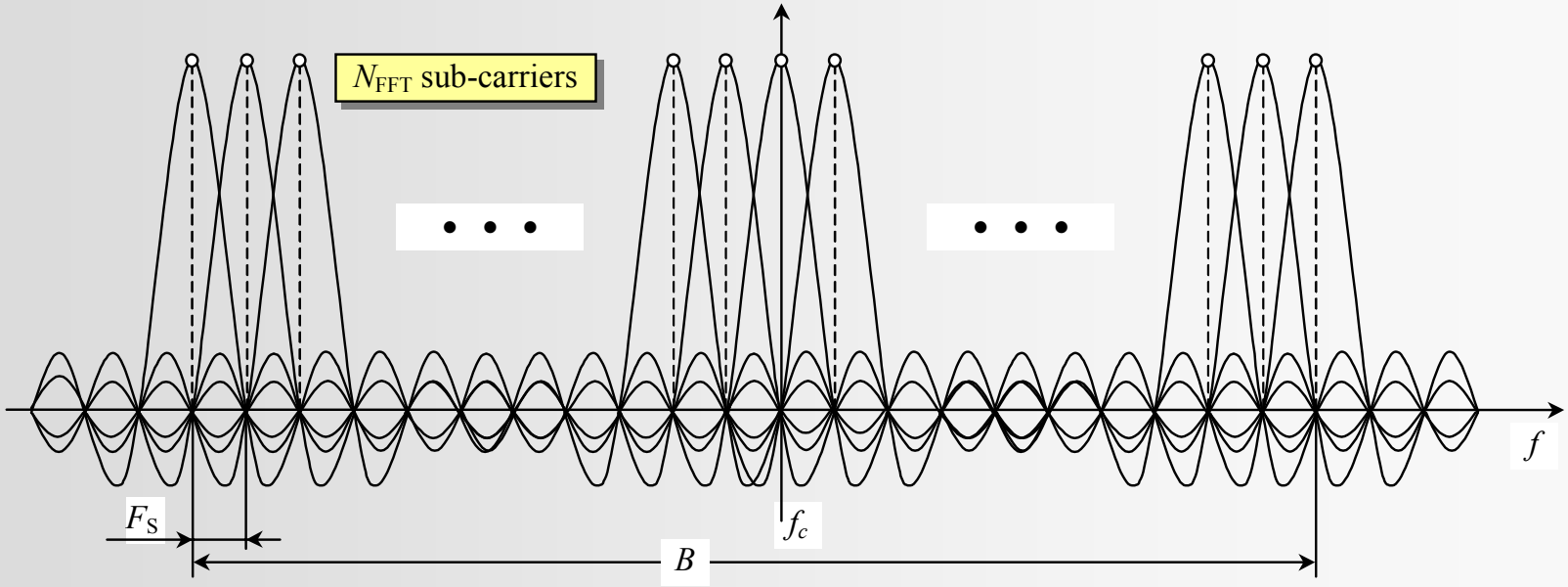
Advantages

– Flat Fading per carrier
– N long pulses
– ISI is comparatively short
– N short EQs needed
– Poor spectral efficiency because of band guards

To improve the spectral efficiency:
Eliminate band guards between carriers
use orthogonal carriers (allowing overlapping)

OFDM
Orthogonal Frequency Division Multiplexing

Distribution of a high rate data stream on many orthogonal subcarriers with low data rate



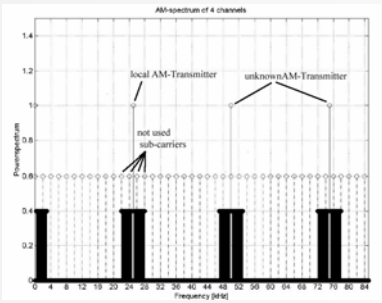
B : Bandwidth
F_S : Subcarrier Spacing
f_c : Carrier Frequency

OFDM Multi-Carrier Modulation
Advantages

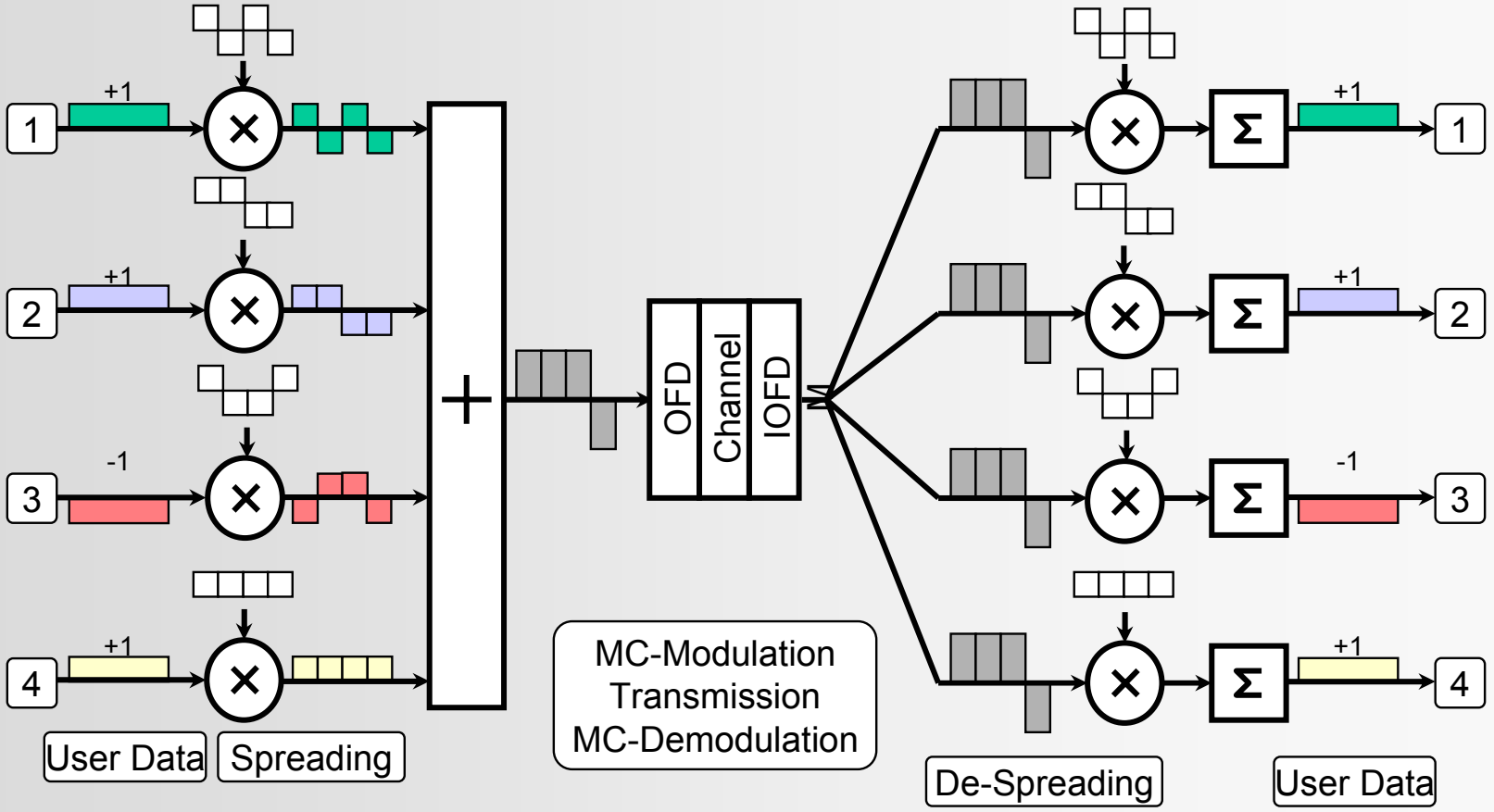
- Increase of spectral efficiency
- Decrease of equalization complexity
- Robust against multi-path propagation effects
- Efficient modulation algorithm available (IFFT, FFT)
- System can be designed to fit requirements perfectly
  - Bandwidth
  - Transmission channel
- No continuous spectrum required
  - Sector-oriented exclusion of VHF frequencies used for DSB-AM & VDL
  - in the near-by sectors it is possible to minimize interference

Characteristics of MC-CDMA

- CDMA introduces multiple channel access
- Number of users can be exchanged with available bandwidth per user
  - flexible bandwidth assignment to users
- Robust against narrowband interferers / attacks / jamming
- Performance improvement through spreading gain
- Resistant against slow / fast frequency selective fading channel
- Reduced re-use distance
  - simple frequency planning



MC-CDMA Example



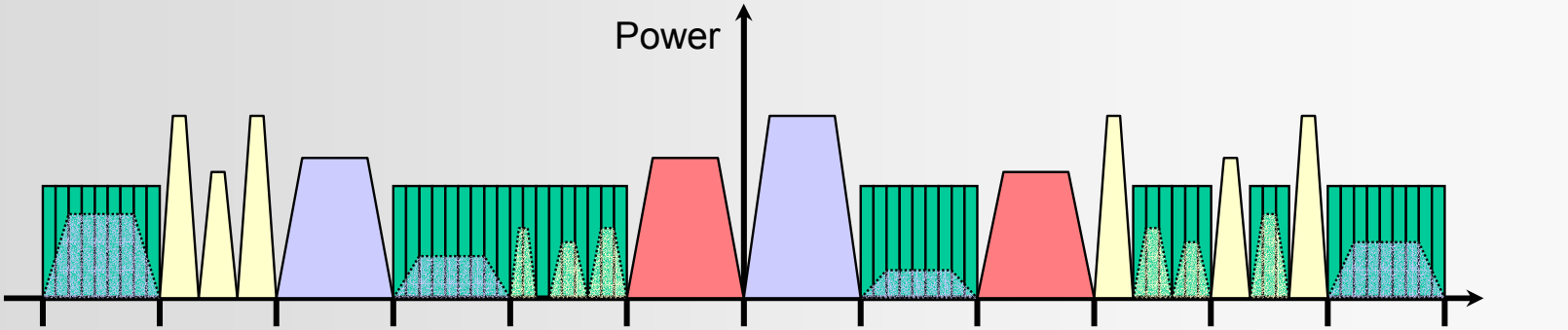
Transition Concepts (Overlay)

- B-VHF and narrowband operate in the same sector simultaneously
  - every A/C equipped with either one technology may be serviced
  - high effort to suppress close NB signals
  - minimize power level of B-VHF transmitter used by local NB
  - lowest system capacity during transition
- B-VHF restricted to selected sectors/areas (e.g. en route)
  - B-VHF equipment mandatory to enter airspace
  - lower number of stronger interferer
  - increased system capacity
- Shift terminal frequencies to different spectrum (e.g. MLS)

Future B-VHF Environment

Transition Phase

Channel allocation remains unchanged for DSB-AM & VDL channels
'Distant' VHF channels can be locally re-used for the new B-VHF system
'Old' DSB-AM / VDL equipment remains untouched

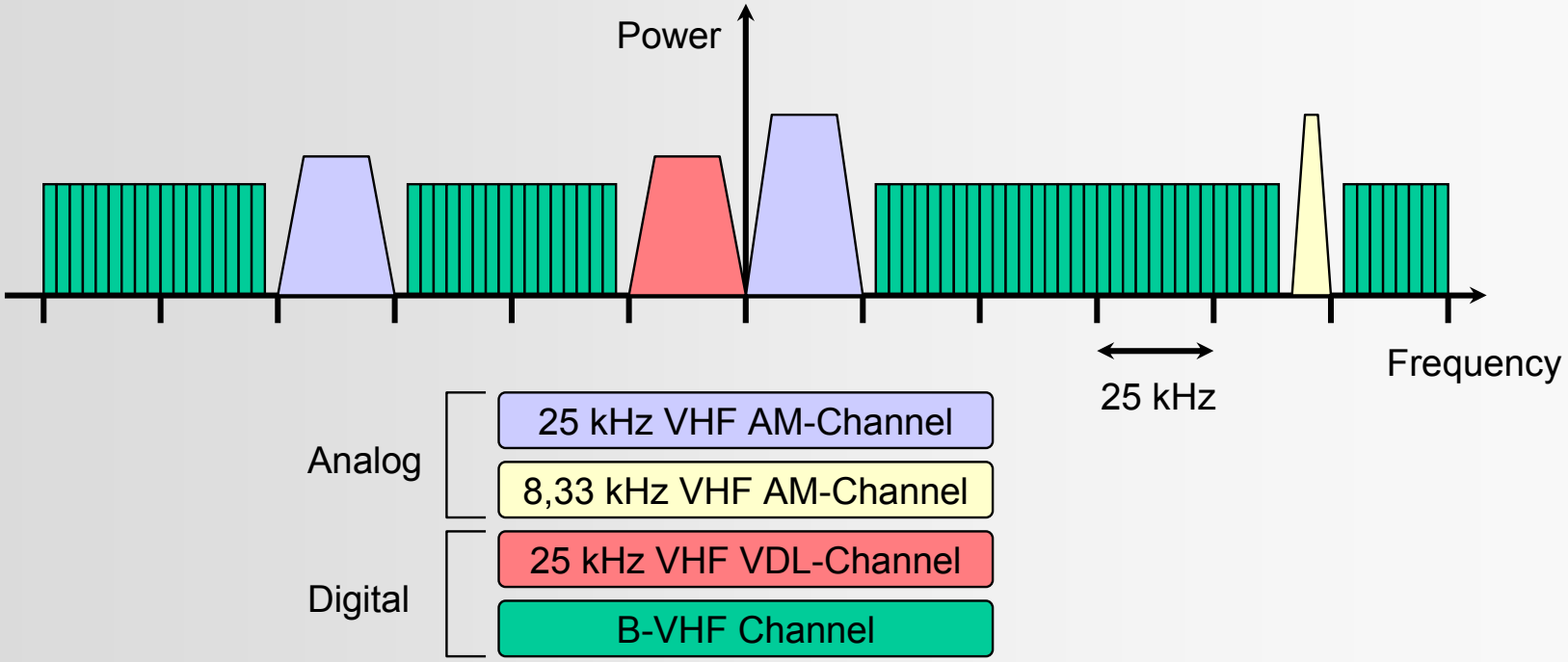


Analog	25 kHz VHF AM-Channel
	8,33 kHz VHF AM-Channel
Digital	25 kHz VHF VDL-Channel
	B-VHF Channel

Future B-VHF Environment

Completion Phase

DSB-AM & VDL channels progressively replaced by the new system
'Distant' VHF channels can be locally re-used for the new B-VHF system
'Old' DSB-AM / VDL equipment remains untouched



Issues to be addressed for B-VHF

- Used DSB-AM / VDL channels in a region need to be known by the system
- Avoidance of mutual interference with existing DSB-AM / VDL channels
  - adaptive Receiver/Transmitter
- Multi-user access technique for up- and downlink
  - CDMA, FDMA, TDMA
  - Sub-channel mapping to users/user groups
- Multiplexing technique e.g. for half-duplex voice/full-duplex data
  - FDD – Frequency Division Duplex
  - TDD – Time Division Duplex
- Simultaneous support for data & voice communications

Europe funds B-VHF project

Research Proposal of the B-VHF consortium has been accepted

- The European Commission is funding the B-VHF activities within the 6th Framework programme
- B-VHF Project
  - Start 1.1.2004
  - End: 30.6.2006
  - Volume: 2,9 mio €
  - Partner: 11

The B-VHF Consortium

Well balanced group covering technical and operational issues

Frequentis G.m.b.H	*Austria*
German Aerospace Center (DLR)	*Germany*
NATS	*UK*
Polytechnic University of Madrid	*Spain*
Ghent University	*Belgium*
BAE Systems (Operations) Ltd.	*UK*
University of Salzburg	*Austria*
Scientific Generics Ltd	*UK*
Lufthansa German Airlines	*Germany*
Deutsche Flugsicherung GmbH (DFS)	Germany
University of Las Palmas de Gran Canaria	*Spain*

B-VHF runs for challenging goals

The main objectives of the B-VHF project

- Proof suitability of MC-CDMA technology
- Proof increased communications performance
- Proof flexible service applicability
- Proof increased security
- Proof of operational feasibility of deployment concept
- Proof feasibility of overlay concept in the VHF band

Thank you for your attention!

B-VHF Consortium Co-ordinator:
johannes.prinz@frequentis.com